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European Patent Office  
Office européen des brevets

⑯ Publication number: 0 112 577  
B2

⑯

## NEW EUROPEAN PATENT SPECIFICATION

⑯ Date of publication of the new patent specification:  
28.02.90

⑯ Int. Cl. 5: H 01 F 1/26, H 01 F 41/02

⑯ Application number: 83113121.4

⑯ Date of filing: 27.12.83

⑯ Magnetic core and method of producing the same.

⑯ Priority: 27.12.82 JP 226736/82  
08.07.83 JP 124408/83

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⑯ Date of publication of application:  
04.07.84 Bulletin 84/27

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⑯ Publication of the grant of the patent:  
20.08.86 Bulletin 86/34

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⑯ Mention of the opposition decision:  
28.02.90 Bulletin 90/09

⑯ Designated Contracting States:  
DE FR GB SE

⑯ References cited:  
EP-A-0 087 781  
DE-A-2 628 207  
GB-A-403 368  
GB-A-578 250  
US-A-3 602 986  
US-A-3 666 571  
US-A-4 320 080  
R. BOLL "Weichmagnetische Werkstoffe", 3rd edition,  
1977 VACUUMSCHMELZE GMBH, Hanau, pp. 43-49

IEEE Transactions on magnetics, Sept. 1972, p.682

R.S. Tebble, D.J. Craik, "Magnetic Materials", Wiley  
Interscience, London, 1969, pp. 544-5

S. Chikazumi, S. Charap, "Physics of Magnetism",  
Robert E. Krieger Publ. Co., Malabar, 1964,

Handbook of Chemistry and Physics, CRC Press, 1976-  
77, p.C-799

**Description****Background of the Invention**

5 This invention relates to a magnetic core, more particularly to a magnetic core which is excellent in the frequency characteristic of magnetic permeability and also has a high magnetic flux density. It also relates to a method of producing the magnetic core.

10 In the prior art, in electrical instruments such as an electric power converting device, including a device for converting an alternating current to a direct current, a device for converting an alternating current having a certain frequency to another alternating current having a different frequency and a device for converting a direct current to an alternating current such as so called inverter, or a non-contact breaker, etc., there have been employed, as electrical circuit constituent elements thereof, semiconductor switching elements, typically thyristor and transistor, and reactors for relaxation of turn-on stress in a semiconductor switching element, reactors for forced comutation, reactors for energy accumulation or transformers for matching connected to these elements.

15 As an example of such electric power converting devices, Fig. 1 shows an electrical circuit of a device for converting a direct current to an alternating current. The electric power converting device as shown in Fig. 1 is constituted of a thyristor 1, a reactor for relaxation of turn-on stress of semiconductor switching element 2 and a transformer for matching 3. Numeral 4 designates load on alternating current and numeral 5 a direct current power source.

20 Through these reactors or transformers, a current containing a high frequency component reaching 100 KHz or higher, even to the extent over 500 KHz in some cases, may sometimes pass on switching of the semiconductors.

25 As the magnetic core constituting such a reactor or a transformer, there have been employed in the prior art such materials as shown below. That is, there may be mentioned:

- 25 (a) a laminated magnetic core produced by laminating thin electromagnetic steel plates or permalloy plates having applied interlayer insulations;
- (b) a so-called dust core produced by caking carbonyl iron minute powder or permalloy minute powder with the use of, for example, a resin such as a phenolic resin; or
- 30 (c) a so-called ferrite core produced by sintering an oxide type magnetic material.

35 Among these, a laminated magnetic core, while it exhibits excellent electric characteristics at a commercial frequency band, is marked in iron loss of the magnetic core at higher frequency band, particularly increased eddy-current loss in proportion to the square of a frequency. It has also the property that the magnetizing power can resist change at inner portions farther from the surface of plate materials constituting the magnetic core because of the eddy-current of the magnetic core material. Accordingly, a laminated magnetic core can be used only at a magnetic flux density by far lower than the saturated magnetic flux density inherently possessed by the magnetic core material itself, and there is also involved the problem of a very great eddy-current loss. Further, a laminated magnetic core has a problem of extremely lower effective magnetic permeability relative to higher frequency, as compared with that relative to commercial frequency. When a laminated magnetic core having these problems is to be used in a reactor, a transformer, etc. connected to a semiconductor switching element through which a current having a high frequency component passes, the magnetic core itself must be made to have great dimensions to compensate for effective magnetic permeability and magnetic flux density, whereby, also because of lower effective magnetic permeability, there is also involved the problem of increased copper loss.

40 45 On the other hand, there is employed as the magnetic core material a compressed powdery magnetic body called as dust core, as described in detail in, for example, Japanese Patent No. 112235. However, such dust cores generally have considerably lower values of magnetic flux and magnetic permeability. Among them, even a dust core using carbonyl iron powder having a relatively higher magnetic flux density has a magnetic flux density of only about 0.1 T and a magnetic permeability of only about  $1.25 \times 10^{-5}$  H/m at a magnetizing force of 10 000 A/m. Accordingly, in a reactor or a transformer using a dust core as the magnetic core material, the magnetic core must inevitably be made to have great dimensions, whereby there is involved the problem of increased copper loss in a reactor or a transformer.

50 55 60 Alternatively, a ferrite core employed in a small scale electrical instrument has a high resistivity value and a relatively excellent high frequency characteristic. However, a ferrite core has a magnetic flux density as low as about 0.4 T at a magnetizing force of 10 000 A/m, and the values of magnetic permeability and the magnetic flux density at the same magnetizing force are respectively varied by some ten percents at -40 to 120°C, which is the temperature range useful for the magnetic core. For this reason, when a ferrite core is to be used as an magnetic core material for a reactor or a transformer connected to a semiconductor switching element, the magnetic core must be enlarged because of the small magnetic flux density. But, a ferrite core, which is a sintered product, can be produced with a great size only with difficulty and thus is not suitable as the magnetic core. Also, a ferrite core involves the problems of great copper loss caused by its low magnetic flux density, of its great characteristic change when applied for a reactor or a transformer due to the great influence by temperatures on magnetic permeability and magnetic flux density, and further of increased noise generated from the magnetic core due to the greater magnetic distortion, as compared with an silicon steel, etc.

65 An object of this invention is to provide an magnetic core to be used for a reactor or a transformer con-

nected to a semiconductor element, which has overcome the problems as described above, having an excellent frequency characteristic of magnetic permeability and a high magnetic flux density.

## 5 Summary of the Invention

The magnetic core of this invention is a molded product according to claim 1.  
The invention also comprises a method of producing such a magnetic core.

10

## Brief description of the drawings

Fig. 1 shows an example of an electric circuit in a device for converting direct current to alternating current;  
Fig. 2 shows direct current magnetization curves in the magnetic core of this invention (Example 3) and a dust core of a prior art; and  
Fig. 3 shows a characteristic diagram representing the magnetic flux density of magnetic cores obtained in Example 13 of this invention.

## 20 Description of the preferred embodiments

The magnetic powder of iron and/or an iron alloy to be used in this invention is required to have a mean particle size of 10 to 100  $\mu\text{m}$ . This is because the aforesaid magnetic powder has a resistivity of  $10 \mu\Omega \cdot \text{cm}$  to some ten  $\mu\Omega \cdot \text{cm}$  at the highest, and therefore in order to obtain sufficient magnetic core material characteristics even in an alternating current containing high frequencies yielding skin effect, the magnetic powder must be made into minute particles, thereby to have the particles from their surfaces to inner portions contribute sufficiently to magnetization. However, if the mean particle size is extremely small, namely less than  $10 \mu\text{m}$ , when molded at the molding stage as hereinafter described under a molding pressure of 10 000 MPa or lower, the density of the resultant magnetic core will not be sufficiently large, resulting in an inconvenience of lowering of magnetic flux density. Consequently, in the present invention, the mean particle size of iron powder or iron alloy magnetic powder is set within the range from  $10 \mu\text{m}$  to  $100 \mu\text{m}$ .

30 Referring now to the relation between the mean particle size ( $D \mu\text{m}$ ) of these powders and resistivity thereof ( $\rho \mu\Omega \cdot \text{cm}$ ), it is preferred to satisfy the relation of  $\rho/D^2 \geq 4 \times 10^{-3}$  as represented by only the values of  $D$  and  $\rho$ .

The iron powder or iron alloy magnetic powder is not particularly limited, but any desired powder may be available, so long as it can satisfy the various parameters as mentioned above, including, for example, powder of pure iron, Fe-Si alloy powder, typically Fe-3 % Si alloy powder, Fe-Al alloy powder, Fe-Si-Al alloy powder, Fe-Ni alloy powder, Fe-Co alloy powder and the like, and each one or suitable combination of these can be employed.

40 The insulating binder resin to be used in this invention has the function of a binder to bind the particles of the aforesaid iron powder or iron alloy magnetic powder, simultaneously with insulation of the particles of the iron powder or iron alloy magnetic powder from each other by coating of the surfaces thereof, thereby imparting sufficient effective resistivity value for alternating current magnetization to the magnetic core as a whole. As such binder resins, there may be included various thermosetting and thermoplastic resins such as epoxy resins, polyamide resins, polyimide resins, polyester resins, polycarbonate resins, polyacetal resins, polysulfone resins, polyphenylene oxide resins and the like, and each one or a suitable combination of these resins may be used.

45 On the other hand, the powder of an insulating inorganic compound also fulfills the function of enhancing the effective resistivity value for alternating current magnetization to the magnetic core as a whole by existing among the particles of the iron conductive powder or iron alloy magnetic powder, simultaneously with enhancement of molding density of the magnetic core through reduction of frictional resistance between the particles of the iron powder or iron alloy magnetic powder during molding of the magnetic core. As such inorganic compounds, there may be included calcium carbonate, silica, magnesia, alumina, hematite, mica, various glasses or a suitable combination thereof. Of course, these inorganic compounds are required to be not reactive with the above-mentioned iron powder or iron alloy magnetic powder and the binder resin.

50 As to the mean particle size of the inorganic compound powder, it is preferably 1/5 or less of the mean particle size of the iron powder or iron alloy magnetic powder, namely, it is  $20 \mu\text{m}$  or less, in view of its dispersibility as well as the relation to the characteristics of the magnetic core material.

55 In the magnetic core of this invention, the total amount of the binder resin and the inorganic compound powder, relative to the whole volume, should be set at the range of from 1.5 to 40 %. When the volume ratio is less than 1.5 %, the molding density of the magnetic core cannot be enhanced and the effective resistivity value is also lowered. On the other hand, in excess of 40 %, the increasing tendency of the effective resistivity value will reach the saturated state, and further the molding density is lowered to result also in lowering of the saturated magnetic flux density, whereby the magnetic flux density under a magnetization force of 10 000 A/m will become similar to that of ferrite.

60 To mention the volume ratio mutually between the binder resin and the inorganic compound powder, the ratio of the former to the latter may be 98 to 20 vol.-%: 2 to 80 vol.-%, preferably 95 to 30 vol.-%: 5 to 70 vol.-%.

5 The magnetic core of this invention may be produced, for example, as follows. That is, predetermined amounts of the three components of i) iron powder, iron alloy magnetic powder or a mixture thereof, ii) binder resin and iii) inorganic compound powder are sufficiently mixed by a mixer and the resultant mixture is then compression molded in a mold. The molding pressure applied may be generally 1000 MPa or lower. If necessary, a heat treatment at a temperature of about 30 to 300°C may also be applied on the molded product for curing of the binder resin.

10 Alternatively, as a preferred embodiment of the method, the above steps for mixing the iron powder and/or the iron alloy magnetic powder may be carried out by first mixing the insulating inorganic compound powder with the resin to prepare a powdery product which is used as a powdery binder, and then mixing the powdery binder with the iron powder and/or the iron alloy magnetic powder. Thereafter the compression molding and the optional heat treatment may be carried out to produce the magnetic core.

15 Accordingly, in the above preferred embodiment, the method of producing an magnetic core according to this invention comprises a step of preparing a binder by mixing an insulating inorganic compound powder with a resin, a step of grinding said binder into a powder to prepare a powdery binder, and a step of mixing and compression molding said powdery binder with iron powder, iron alloy magnetic powder or a mixture thereof.

20 According to this method, the powdery binder is held homogeneously among the particles of the magnetic powder when the powdery binder is mixed with the magnetic powder of iron or iron alloy magnetic material. When the mixture is further compression molded, the inorganic compound powder having been homogeneously compounded in the powdery binder plays role as a carrier for introducing the resin into the spaces formed among the particles, whereby the resin is very homogeneously dispersed among the particles of the magnetic powder. As a result, a thin insulating layer can be surely formed among the particles and therefore it becomes possible to produce an magnetic core having large resistivity, namely, having large magnetic flux density and excellent frequency characteristic of magnetic permeability.

25 Moreover, the inorganic compound powder and the resin which have been effectively held among the particles of the magnetic powder may decrease the frictional resistance between the particles, whereby it becomes possible to enhance the space factor of the particles of the magnetic powder even under molding pressure of not more than 1000 MPa, preferably 100 to 1000 MPa, which is readily utilizable in an industrial field. An magnetic core having higher magnetic flux density can therefore be produced.

30 This invention will be described in greater detail by the following Examples.

### Examples 1 - 7

35 Various kinds of magnetic powder, inorganic powder, having different mean particle sizes, and binder resins were formulated at the ratios (vol.-%) indicated in Table 1, and these were sufficiently mixed. Each of the resultant mixtures was filled in a mold for molding of magnetic core, in which compression molding was carried out under various prescribed pressures to a desired shape. The molded product was subjected to heat treatment for curing of the binder resin to provide an magnetic core.

40 For these magnetic cores, density, magnetic flux density under magnetization force of 10 000 A/m were measured, and further effective resistivity was calculated from the eddy-current loss of the magnetic core relative to alternate current magnetization.

45 For comparison, also produced were those using the materials having compositional proportions outside this invention (Comparative examples 1 and 2), those containing no inorganic compound powder (Comparative example 3) and those using magnetic powder of mean particle sizes outside this invention (Comparative examples 4 and 5).

Results are summarized in Table 1.

50 TABLE 1

55	Example No.	Kind	Components formulated					
			Magnetic powder		Inorganic compound powder		Binder resin	
			Mean particle size(μm)	Formulated ratio (vol. %)	Kind	Mean particle size(μm)	Formulated ratio (vol. %)	Kind
60	1	Fe-0.5Si	37 - 50	98.4	CaCO <sub>3</sub>	2.7	0.08	Epoxy
	2	"	"	90.0	"	"	2.0	"
	3	"	"	80.0	"	"	12.0	"
	4	"	"	65.0	"	"	20.0	"
	5	Fe-4.5Si	53 - 63	75.0	Alumina	5.7	5.0	Epoxy
	6	Fe	44.7	98.4	Silica	0.17	0.1	Poly- amide
65	7	"	100	"	"	"	"	"

Comparative example		Fe-0.5Si	37 - 50	99.0	CaCO <sub>3</sub>	2.7	0.08	Epoxy	0.92
5	2	"	"	55.0	"	2	5.0	"	40.0
3	Fe-4.5Si	53 - 63	75.0	"	"	"	"	Epoxy	25.0
4	Fe	150	98.4	Silica	0.17	0.1	Poly- amide	1.5	
5	"	250	"	"	"	"	"	"	"

10

TABLE 1 (Cont'd)

15	Example No.	Molding pressure (MPa)	Heating condition (°C, hr)	Characteristics of magnetic core		
				Density (g/cm <sup>3</sup> )	Magnetic flux density (T:Hm = 10 000A/m)	Effective resistivity (mΩ · cm)
1	600	200, 1	7.4	1.44	80	
2	"	"	7.0	1.22	280	
3	"	"	6.5	1.12	430	
20	4	"	5.4	0.66	540	
5	800	200, 1	6.1	0.78	550	
6	500	150, 1	7.4	1.44	70	
7	"	"	7.4	1.46	22	
25	Comparative example					
1	600	200, 1	7.4	1.42	15	
2	"	"	4.7	0.37	600	
3	800	200, 1	5.7	0.66	540	
30	4	500	160, 1	7.4	1.44	6
5	"	"	7.4	1.46	5	

35 When the magnetic cores of Examples 1 to 4 were subjected to measurements of changes in magnetic permeability and magnetic flux density at temperatures of from -40 to 120°C, the percent changes obtained were all less than 10 %.

Fig. 2 shows direct current magnetization curves representing changes in magnetic flux density for respective magnetizing forces, which were determined for the direct magnetization characteristic of the magnetic core of Example 3 and the magnetic core comprising the dust core of the prior art. It was confirmed that the magnetic core of this invention (curve A) was excellent, having higher magnetic flux density, as compared with the magnetic core of the prior art (curve B).

### Examples 8 - 11

45 Mixtures prepared by mixing 84 vol.-% of iron powders or iron alloy magnetic powders having different resistivities (ρ) and mean particle sizes (D), 1 vol.-% of an alumina powder having a mean particle size of 1 μm or less and 15 vol.-% of an epoxy resin were each molded under a pressure of 600 MPa, and heat treatment was applied on each product at 200°C for 1 hour to provide an magnetic core.

50 For these magnetic cores, effective magnetic permeabilities at 1 kHz to 500 kHz were measured, and the ratios were determined relative to the effective magnetic permeability at 1 kHz as the standard. The results are shown in Table 2 as the relation with ρ/D<sup>2</sup>.

TABLE 2

55	Example	Iron or iron-based alloy powder*			Changes of effective magnetic permeability (1 kHz = 1)			
		Restivity (ρμΩ · cm)	Mean particle size D μm	ρ/D <sup>2</sup>	1 kHz	100 kHz	300 kHz	500 kHz
60	8	45	97	4.78 x 10 <sup>-3</sup>	1	1.00	0.98	0.95
9	80	50	3.2 x 10 <sup>-2</sup>	1	1.00	0.99	0.98	
10	27	69	5.67 x 10 <sup>-3</sup>	1	1.00	0.98	0.95	
11	10	44	5.17 x 10 <sup>-3</sup>	1	1.00	0.98	0.95	

65

Comparative  
example

5	6	45	115	$3.4 \times 10^{-3}$	1	0.98	0.90	0.86
	7	10	53	$3.56 \times 10^{-3}$	1	0.98	0.89	0.77
	8	10	97	$1.06 \times 10^{-3}$	1	0.97	0.78	0.64
	9	27	105	$2.44 \times 10^{-3}$	1	0.98	0.89	0.84
10	10	Laminated magnetic core of 25 $\mu$ permalloy sheet			1	0.8	0.62	0.36

\* Composition:

Example 8: Fe-3 % Si  
Example 9: Fe-6.5 % Si  
Example 10: Fe-1.5 % Si  
Example 11: Pure iron

Comparative example 6: Fe-3 % Si  
Comparative example 7: Pure iron  
Comparative example 8: Pure iron  
Comparative example 9: Fe-1.5 % Si

**Example 12**

20 A mixture prepared by mixing 40 vol.-% of Fe-3 Al powder having a mean particle size of 63  $\mu$ m, 10 vol.-% of Fe-Ni powder having a mean particle size of 53  $\mu$ m or less, Fe powder having a mean particle size of 44  $\mu$ m, 0.8 vol.-% of glass powder having a mean particle size of 8  $\mu$ m and 14.2 vol.-% of a polyamide resin was compression molded under a pressure of 800 MPa, followed by heat treatment at 100°C for 1 hour, to provide an magnetic core. This magnetic core was found to have an effective resistivity of 350  $\text{m}\Omega \cdot \text{cm}$ .

25 In the above Examples, when an polyimide resin or a polycarbonate resin was employed in place of the epoxy resin, or when other inorganic compounds such as magnesia were employed, the same results could also be obtained.

**Example 13**

30 Inorganic compound of  $\text{SiO}_2$  (silica) powder having mean particle sizes of 3  $\mu$ m was mixed into a solution of thermosetting resin of epoxy resin with the addition of an amine type binder, 4,4'-diaminodiphenylmethane (DDM) or m-phenylenediamine (MPD), which were kneaded under heating at 60°C to 110°C to prepare a binder comprising a mixture of the  $\text{SiO}_2$  powder and the epoxy resin. According to this procedure, prepared were 6 kinds of binders containing therein the silica powder in an amount of 5, 20, 30, 48, 65 and 80 % in terms of volume ratio, respectively.

35 After allowing the binders to stand until each of the epoxy resins contained therein assumed a half-cured state, these were subjected to extrusion processing and grinding processing to prepare powdery binders having particles sizes of 50 to 150  $\mu$ m.

40 Each of these six kinds of the powdery binders and Fe-1.8 % Si alloy powder having mean particle size of 44  $\mu$ m to 63  $\mu$ m were mixed with each other in the ratio of 25 : 75 in parts by volume. Each of the powdery mixtures thus prepared was packed in a metallic mold and compression molded under pressure of 500 MPa, followed by heat treatment at 200°C for 1 hour to produce six kinds of magnetic cores.

45 Thereafter, values for the magnetic flux density of these six kinds of magnetic cores under the external magnetization field of 10 000 AT/m were examined to obtain the results as shown in Fig. 3. In Fig. 3, abscissa is the ratios of the content of silica powder in the binder resin; the mark  $\Delta$  denotes a result of a comparative example where no silica powder is contained at all in the binder resin.

50 As is apparent from Fig. 3, the higher the ratio of the content of silica powder in the binder resin is, the better the magnetic flux density is improved. This is because the frictional resistance between the particles of the magnetic powder decreases owing to the rolling action of the silica powder and the presence of the resin dispersed among the particles of the magnetic powder and, as a result, the space factor of the Fe-1.8 % Si alloy powder in the magnetic core has been improved. Moreover, it has been found and confirmed that the magnetic cores thus produced have effective electrical resistivity of 500  $\text{m}\Omega \cdot \text{cm}$  or higher which is a remarkably improved value as compared with the resistivity (30  $\text{m}\Omega \cdot \text{cm}$  or lower) of conventional magnetic cores, and also have excellent high frequency characteristics.

**Example 14**

60 Inorganic compound of  $\text{CaCO}_3$  powder having mean particle size of 2  $\mu$ m was mixed with a thermosetting resin of polyamide resin at the proportion of 25 % in terms of volume relative to the resin, and the mixture was subjected to cooling processing and extrusion processing to prepare a binder in a solid form, which was then milled or ground to obtain a powdery binder having particle size of 74  $\mu$ m or less.

65 The powdery binder was then mixed with Fe-1.5 % Si alloy powder having mean particle size of 63  $\mu$ m. According to these procedures, prepared were four kinds of mixed materials (Sample Nos. 1 to 4) containing

therein the magnetic alloy powder in an amount of 55, 65, 98 and 99 % in terms of volume ratio, respectively. (Sample Nos. 1 and 2 are comparative examples, however.)

Thereafter, the mixed materials were compression molded under the pressure of 800 MPa, followed by heat treatment at a resin-softening temperature to produce the corresponding four kinds of magnetic cores.

Values for the magnetic flux density of these magnetic cores under the external magnetization field of 10 000 AT/m were examined to obtain the results as shown in Table 3.

TABLE 3

Sample No.	Binder resin (vol %)	Magnetic powder (vol %)	Magnetic flux density (T) (Hm = 10 000 AT/m)	Effective resistivity (mΩ · cm)
1	1.0	99	1.4	16
2	2.0	98	1.4	95
3	35	65	0.6	510
4	45	55	0.35	610

As is apparent from Table 3, the magnetic flux density of a core is lower than that in the case of a ferrite core when the content of the binder in the magnetic core exceeds 40 %, while very high magnetic flux density can be obtained when the content is not more than 40 %. The effective resistivity of magnetic core is extremely lowered to a value pertaining to conventional one when the above content is not more than 1.5 %, while it is confirmed that very high value can be obtained when the content is not less than 1.5 %.

Thus, it is possible to obtain magnetic cores suited for intended use by controlling the content of the binder in an magnetic core.

The inorganic compounds, the binder resin and the magnetic powder mentioned in the above are not limited to those used in the above Examples, but there may be used mica, alumina or the like.

As apparently seen from Examples, the magnetic core of this invention has a magnetic flux density by far greater than the magnetic core of ferrite core or the magnetic core of dust core of the prior art, and also has a high effective resistivity. Further, also when compared with the laminated magnetic core, the core of this invention is smaller in change of effective magnetic permeability at a frequency band region from 1 to 500 kHz, and its commercial value is great.

35

### Claims

1. A magnetic core, which comprises a molded product comprising:  
either one or both of an iron powder and an iron alloy magnetic powder having a mean particle size represented by  $D_{\mu\text{m}}$  of 10 to 100  $\mu\text{m}$ , and a resistivity represented by  $\mu\Omega \cdot \text{cm}$  such that when  $p$  and  $D$  are represented in terms of only their numerical values, the relationship  $p/D^2 \geq 4 \times 10^3$  is satisfied; and  
1.5 to 40 %, as a total amount in terms of volume ratio, of insulating binder resin and insulating inorganic compound powder.
2. A magnetic core according to Claim 1, wherein said inorganic compound powder has a mean particle size of 20  $\mu\text{m}$  or less.
3. A magnetic core according to Claim 1, wherein said iron powder or iron alloy magnetic powder is at least one selected from the group consisting of Fe powder, Fe-Si alloy powder, Fe-Al alloy powder, Fe-Si-Al alloy powder, Fe-Ni alloy powder and Fe-Co alloy powder.
4. A magnetic core according to Claim 1, wherein said insulating binder resin is at least one selected from the group consisting of epoxy resins, polyamide resins, polyimide resins, polyester resins, polycarbonate resins, polyacetal resins, polysulfone resins and polyphenylene oxide resins.
5. A magnetic core according to Claim 1, wherein said insulating inorganic compound powder is powder of at least one compound selected from the group consisting of calcium carbonate, silica, magnesia, alumina, red iron oxide and glass.
6. A magnetic core according to Claim 5, wherein said insulating inorganic compound powder has a mean particle size of 1/5 or less of the mean particle size of the iron powder or iron alloy magnetic powder.
7. The magnetic core according to Claim 1, wherein the ratio of said binder resin and said inorganic compound powder is 98 to 20 vol.-% : 2 to 80 vol.-%.
8. A method of producing a magnetic core, which comprises the steps of:

5 preparing a binder by mixing an insulating inorganic compound powder with a resin, grinding said binder into a powder to prepare a powdery binder, and

mixing and compression molding 1.5 to 40 %, as a total amount in terms of volume ratio, of said powdery binder with iron powder, iron alloy magnetic powder or a mixture thereof, having a mean particle size represented by  $D \mu\text{m}$  of 10 to 100  $\mu\text{m}$ , and a resistivity represented by  $\rho \mu\Omega \cdot \text{cm}$  such that when  $\rho$  and  $D$  are represented in terms of only their numerical values, the relationship  $\rho/D^2 \geq 4 \times 10^{-3}$  is satisfied.

9. A method according to Claim 8, wherein the compression molding is carried out under a pressure of from 100 to 1000 MPa.

10

### Patentansprüche

15 1. Magnetischer Kern, der ein Formprodukt umfaßt, das ein Eisenpulver und/oder ein magnetisches Eisenlegierungspulver mit einer durchschnittlichen Teilchengröße, die durch  $D \mu\text{m}$  dargestellt wird, von 10 bis 100  $\mu\text{m}$ , und einem Widerstand, dargestellt durch  $\rho \mu\Omega \cdot \text{cm}$ , derart, daß, wenn  $\rho$  und  $D$  allein durch ihre numerischen Werte dargestellt sind, der Zusammenhang  $\rho/D^2 \geq 4 \times 10^{-3}$  erfüllt ist; und

1.5 bis 40 %, als Gesamtmenge in Bezug auf das Volumenverhältnis, eines isolierenden Binderharzes und eines isolierenden Pulvers einer anorganischen Verbindung umfaßt.

20

2. Magnetischer Kern nach Anspruch 1, wobei das Pulver der anorganischen Verbindung eine durchschnittliche Teilchengröße von 20  $\mu\text{m}$  oder weniger besitzt.

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3. Magnetischer Kern nach Anspruch 1, wobei das Eisenpulver oder das magnetische Eisenlegierungspulver mindestens eine Komponente aus der Reihe Fe-Pulver, Fe-Si-Legierungspulver, Fe-Al-Legierungspulver, Fe-Si-Al-Legierungspulver, Fe-Ni-Legierungspulver und Fe-Co-Legierungspulver ist.

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4. Magnetischer Kern nach Anspruch 1, wobei das isolierende Binderharz mindestens eine Komponente aus der Reihe Epoxyharze, Polyamidharze, Polyimidharze, Polyesterharze, Polycarbonatharze, Polyacetalharze, Polysulfonharze und Polyphenylenoxidharze darstellt.

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5. Magnetischer Kern nach Anspruch 1, wobei das isolierende Pulver einer anorganischen Verbindung ein Pulver aus mindestens einer Verbindung, ausgewählt aus der Reihe Calciumcarbonat, Siliziumdioxid, Magnesiumoxid, Aluminiumoxid, rotes Eisenoxid und Glas, ist.

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6. Magnetischer Kern nach Anspruch 5, wobei das isolierende Pulver einer anorganischen Verbindung eine durchschnittliche Teilchengröße von 1/5 oder weniger der durchschnittlichen Teilchengröße des Eisenpulvers oder des magnetischen Eisenlegierungspulvers hat.

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7. Magnetischer Kern nach Anspruch 1, wobei das Verhältnis des Binderharzes und des Pulvers der anorganischen Verbindung 98 bis 20 Vol.-% : 2 bis 8 Vol.-% ist.

8. Verfahren zur Herstellung eines magnetischen Kerns, das die Schritte umfaßt:

Herstellen eines Binders, in dem man ein isolierendes Pulver einer anorganischen Verbindung mit einem Harz vermengt,

Mahlen des Binders zu einem Pulver, um einen pulverförmigen Binder herzustellen, und

Mischen und Druckformen von 1.5 bis 40 %, als Gesamtmenge in Bezug auf das Volumenverhältnis, des pulverförmigen Binders mit Eisenpulver, magnetischem Eisenlegierungspulver oder einer Mischung davon mit einer durchschnittlichen Teilchengröße, dargestellt durch  $D \mu\text{m}$  von 10 bis 100  $\mu\text{m}$ , und einem Widerstand, dargestellt durch  $\rho \mu\Omega \cdot \text{cm}$ , derart, daß wenn  $\rho$  und  $D$  allein durch ihre numerischen Werte dargestellt sind, der Zusammenhang  $\rho/D^2 \geq 4 \times 10^{-3}$  erfüllt ist.

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9. Verfahren nach Anspruch 8, wobei man das Druckformen unter einem Druck von 100 bis 1000 MPa durchführt.

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### Revendications

60 1. Noyau magnétique qui comprend un produit moulé, comprenant:  
soit l'une des deux poudres suivantes, soit les deux, à savoir une poudre de fer et une poudre d'un alliage ferreux magnétique, présentant une dimension moyenne de particule, représentée par  $D (\mu\text{m})$ , de 10 à 100  $\mu\text{m}$ , et une résistivité, représentée par  $\rho (\mu\Omega \cdot \text{cm})$ , telles que les valeurs numériques de  $\rho$  et de  $D$  satisfont la relation  $\rho/D^2 \geq 4 \times 10^{-3}$ ; et

65 de 1.5 à 40 %, quantité totale exprimée en rapport volumique, d'une résine isolante de liant et d'une poudre de composé inorganique isolant.

2. Noyau magnétique conforme à la revendication 1, *dans lequel* ladite poudre de composé inorganique présente une dimension moyenne de particule de 20 µm ou moins.

5 3. Noyau magnétique conforme à la revendication 1, *dans lequel* ladite poudre de fer ou poudre d'alliage ferreux magnétique est au moins une poudre choisie dans le groupe constitué par de la poudre de fer, de la poudre d'alliage Fe-Si, de la poudre d'alliage Fe-Al, de la poudre d'alliage Fe-Si-Al, de la poudre alliage Fe-Ni et de la poudre d'alliage Fe-Co.

10 4. Noyau magnétique conforme à la revendication 1, *dans lequel* ladite résine isolante de liant est au moins une résine choisie dans le groupe constitué des résines époxy, des résines polyamide, des résines polyimide, des résines polyester, des résines polycarbonate, des résines polyacétal, des résines polysulfone et des résines poly(oxyphénylène).

15 5. Noyau magnétique conforme à la revendication 1, *dans lequel* ladite poudre de composé inorganique isolant est une poudre d'au moins un composé choisi dans le groupe constitué par le carbonate de calcium, la silice, la magnésie, l'alumine, l'oxyde ferrique et le verre.

20 6. Noyau magnétique conforme à la revendication 5, *dans lequel* ladite poudre de composé inorganique isolant présente une dimension moyenne de particule inférieure ou égale au cinquième de la dimension moyenne de particule de la poudre de fer ou de la poudre d'alliage ferreux magnétique.

25 7. Noyau magnétique conforme à la revendication 1, dans lequel les proportions de ladite résine de liant et de ladite poudre de composé inorganique sont 98 - 20 % en volume pour 2 - 80 % en volume.

8. Procédé de production d'un noyau magnétique, qui comprend les étapes consistant à:  
 préparer un liant en mélangeant une poudre d'un composé inorganique isolant avec une résine,  
 broyer ledit liant en une poudre pour préparer un liant pulvérulent, et  
 mélanger et mouler par compression 1,5 à 40 %, quantité totale exprimée en rapport volumique, dudit liant pulvérulent avec une poudre de fer, une poudre d'un alliage ferreux magnétique ou un mélange de celles-ci, présentant une dimension moyenne de particule, représentée par D (µm), de 10 à 100 µm et une résistivité, représentée par  $\rho$  ( $\mu\Omega \cdot \text{cm}$ ), telles que les valeurs numériques de  $\rho$  et de D satisfont la relation  $\rho / D^2 \geq 4 \times 10^{-3}$ .

30 9. Procédé conforme à la revendication 8, *dans lequel* le moulage par compression est effectué sous une pression de 100 à 1000 MPa.

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FIG. I

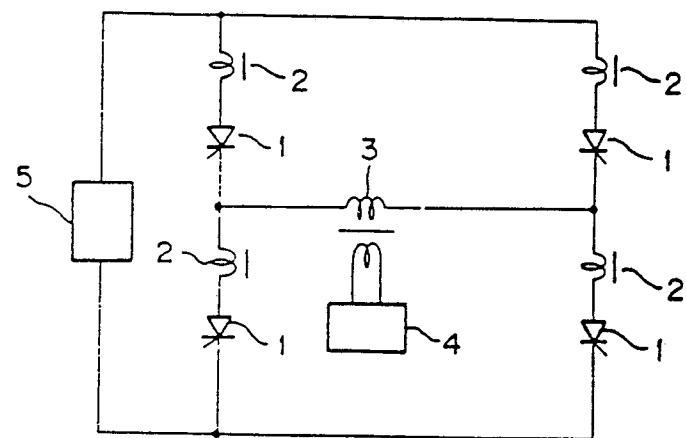


FIG.2

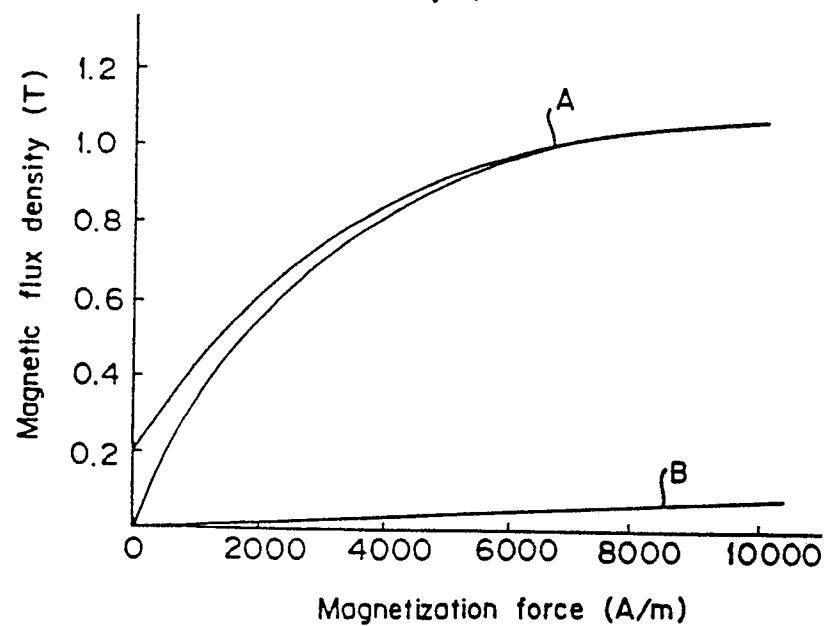


FIG.3

